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with the Crossley reflector, and ephemerides based upon the most probable orbit were furnished him. During the course of his search he discovered three minute planets in the immediate neighborhood of the positions indicated by one of the ephemerides. Enough observations of all three were secured to render it certain that none were identical with 1911 *MT*. This failure to find the planet does not justify the rejection of the orbit upon which the search was based, because the predicted magnitude is very uncertain and the planet may have been in the region photographed, but too dim to be reached even by the Crossley. A more favorable opposition will occur in 1915 and it is hoped that the planet may be recovered at that time.

Berkeley Astronomical Department,
University of California,
1913, April.

A COMPARISON OF PHOTOGRAPHIC WITH THEORETICAL POSITIONS OF MINOR PLANETS: (105) *ARTEMIS,* (115) *THYRA,* (119) *ALTHÆA,* (133) *CYRENE,* (139) *JUEWA,* (174) *PHÆDRA.*

By Anna R. Kidder,
University Fellow in Astronomy, 1912-1913.

"By the will of James C. Watson, who died in 1880, a fund was bequeathed in trust to the National Academy of Sciences for the purpose of promoting astronomical research." Among other things, this was to include "the construction of tables of the minor planets discovered by the testator." In 1901, Professor Leuschner was chosen to direct in person this work, which "was to embrace the numerical development of the perturbations, including terms only of the first order with respect to the mass of *Jupiter,* by Hanson's method; a correction of the elements by means of the differences between the computed and observed positions for all available oppositions; and the construction of tables to facilitate the computation of positions to the nearest minute of arc, from the date of discovery to 1930." [1]

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[1] Tables of minor planets discovered by James C. Watson: Armin O. Leuschner, *Memoirs of the National Academy of Sciences,* Volume X.

In 1910 the first series of these tables were published in Volume X of the *Memoirs of the National Academy of Sciences.* It contains the tables of twelve of the twenty-two minor planets discovered by WATSON. The elements and perturbations in the case of each asteroid are based on oppositions extending from the date of discovery to about 1900, the latest opposition used in any case being that of 1904. It was therefore desirable that the accuracy of the tables be tested by comparison with observations at a much later opposition. Upon investigation, it was found that oppositions of six of these twelve asteroids occurred between September, 1912, and May, 1913, and a comparison between photographic and theoretical positions could thus be made.

The work as outlined included the computation of an ephemeris covering the date of opposition for each asteroid, based upon the tables already referred to; the observation of each asteroid with the photographic telescope at the Students' Observatory; the measurement and reduction of the plates; and a comparison of the photographic positions with those computed. Ephemeris positions of minor planets (105) *Artemis*, (174) *Phædra*, (133) *Cyrene*, (115) *Thyra*, and (139) *Juewa*, were thus computed, according to the directions and following the example given in Volume X of the *Memoirs of the National Academy of Sciences.* For these five asteroids, in opposition in 1912, a comparison between the ephemeris computed and the ephemeris published in the 1914 *Berliner Astronomisches Jahrbuch* could also be made. The 1915 *Jahrbuch*, which gives the opposition ephemeris of the sixth asteroid, (119) *Althæa*, has made use of LEUSCHNER's tables, so that the computation of another ephemeris was unnecessary. All work was checked independently by Miss FLORENCE RYLE. By interpolation from the special tables for the planets the perturbations $n\delta z$, $\delta \log r = \log(1 + v')$, and $u/\cos i$, were formed, with the following result:—

PERTURBATIONS.

		$n\delta z$	$\log(1 + v')$	$u/\cos i$
(105) *Artemis*	Oct. 28.5	$+0^\circ.0116$	-0.000218	$-0^\circ.0698$
(174) *Phædra*	Nov. 27.5	-0 .3366	-0.000508	-0 .0293
(133) *Cyrene*	Dec. 07.5	$+0$ .8492	-0.001462	-0 .0200
(155) *Thyra*	Dec. 17.5	-0 .2287	-0.000589	-0 .0455
(139) *Juewa*	Dec. 07.5	$+1$ .9104	-0.001544	$+0$ .0041

The comparison between the ephemeris positions computed on the basis of LEUSCHNER's elements and perturbations, and the ephemeris published in the 1914 *Berliner Astronomische Jahrbuch,* is shown in the following table. The table shows the comparison for only one date of each ephemeris, the residuals in α and δ being practically constant for all the dates of each ephemeris:—

	Date, Berlin M.T.	LEUSCHNER.		JAHRBUCH.		(B. J. — A. O. L.)	
		α h m	δ ° ′	α h m	δ ° ′	$\Delta\alpha$ m	$\Delta\delta$ ′
(105) *Artemis*	Oct. 28.5	0 53.19	—2 10.8	0 55.3	—2 05	+2.1	+6
(174) *Phædra*	Nov. 27.5	4 50.81	+39 15.7	4 53.8	+39 20	+3.0	+4
(133) *Cyrene*	Dec. 07.5	5 28.73	+32 00.6	5 34.8	+32 00	+6.1	—1
(115) *Thyra*	Dec. 17.5	6 06.41	+38 08.1	6 09.5	+38 05	+3.1	+3
(139) *Juewa*	Dec. 07.5	7 10.59	+39 27.2	7 03.5	+39 36	—7.1	+9

As already stated, no ephemeris was computed for (119) *Althæa,* LEUSCHNER's elements and perturbations being used in the computation of the ephemeris for the planet given in the 1915 *Berliner Jahrbuch.* The residuals in the above table indicate that in every case the position as given by the *Jahrbuch* is in error by an amount which might lead to wrong identification of planets.

To obtain the necessary observations for comparison with the computed positions, photographs were taken with the telescope belonging to the Students' Observatory. This telescope is a doublet combination of the portrait lenses of 5″.5 and 6″ aperture and about 22″ and 30″ focal length, respectively. Two or three photographs were taken for each asteroid except the first, (105) *Artemis,* which it was impossible to get at the time of opposition on account of continuous cloudy weather. The lengths of exposures varied from an hour to an hour and a half, depending upon the magnitude of the asteroid and the atmospheric conditions. There being no micrometer attachment to the photographic telescope, the guiding was done by the slow-motion screws to keep the image of a star, chosen as near the center of the field as possible, upon the cross hairs of the eye-piece. Seed 30 dry plates were used and BARNARD's developer was used in developing them.

The planets (115) *Thyra,* (139) *Juewa,* and (119) *Althæa,* of magnitude 9.4, 10.3 and 9.9 respectively, were easily found in this manner. A careful search of the plates taken for (174) *Phædra* and (133) *Cyrene* was not successful, however. These planets were of magnitudes 12.4 and 12.0 and probably too faint to be found with the instrument used.

The photographic plates were then measured on the Repsold measuring engine. To simplify the measuring of the star plates, it was decided to take all readings from the horizontal scale of the instrument. The plate was to be first so orientated that the readings on the scale would give the x-coördinates directly; then after rotation through 90° in the proper direction, the scale readings would give y directly. Rotating again through 90° would give x reversed, and a third rotation y reversed. This plan was adopted for all plates.

To determine the scale value of the horizontal scale of the Repsold measuring engine, a ten-minute exposure of the *Pleiades* was taken. In spite of the fact that the plates taken with the smaller lens of the photographic telescope gave, in every case, better definition in all parts of the field, it was decided to use those taken with the larger lens, the advantage of larger scale being greater than the disadvantage of larger and less well-defined images. Two complete sets of readings for the seven brighter stars of the *Pleiades* were made from this plate. The right ascension and declination of those stars were taken from Boss's catalogue and transformed by JACOBY's[1] series and tables into rectangular coördinates. The mean of comparison between measured distances on the plate and the computed coördinates gave the scale value $1^{mm} = 259''.65$.

With a few simplifications suggested by PERRINE,[2] JACOBY's "Tables for the Reduction of Astronomical Photographs" were used in the reduction of the measured coördinates to intervals of right ascension and declination. Four or five catalogue stars situated as symmetrically as possible about the asteroid were chosen as comparison stars. To avoid corrections to the center of the plate, the mean of the known right ascensions and declinations, or in other words the center of gravity of the system of comparison stars, is chosen as plate-center; and the rectangular coördinates x and y of each star from the plate-center as origin, are computed by means of JACOBY's series.

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[1] Tables for the reduction of astronomical photographs: HAROLD JACOBY, "Contributions from the Observatory of Columbia University," No. 23.

[2] Preliminary note on "Some Simplifications in the Reductions of Stellar Photographs": C. D. PERRINE, *Lick Observatory Bulletin*, No. 102.

For the three asteroids for which photographic observations were not obtained at the Students' Observatory on account of cloudy weather and faintness of the asteroids themselves, a search was made among the published observations in the *Astronomische Nachrichten.* Photographic observations of (105) *Artemis* and (133) *Cyrene* from Heidelberg were found and these have been used in the comparison made. But for (174) *Phædra* no observation for this opposition has been found, and consequently no comparison for this planet can be made.

The .photographs taken at the Students' Observatory gave the following positions of minor planets:—

			Gr. M. T.	Apparent Position.	
				α	δ
1.	(115) *Thyra*	1912 Dec. 4	$18^h 30^m.0$	$6^h 22^m.33$	$+39° 01'.6$
2.	" "	Dec. 5	18 50 .0	6 21 .21	+38 59 .0
3.	(139) *Juewa*	Dec. 31	17 59 .4	6 45 .45	+40 46 .5
4.	" "	1913 Jan. 2	18 18 .6	6 43 .00	+40 47 .3
5.	(119) *Althæa*	Feb. 27	18 44 .4	10 25 .20	+2 56 .3
6.	" "	Mar. 2	19 12 .2	10 22 .64	+3 16 .4

In the comparison use has also been made of the following observations published in recent numbers of the *Astronomische Nachrichten*:—

			M.Z.Kgst.	α	δ	
7.	(105) *Artemis*	1912 Oct. 7	$9^h 06^m.4$	$1^h 09^m.7$	$+2° 05'$	*A.N.* 4607
3.	" "	Oct. 10	10 18 .0	1 07 .2	+1 24	*A.N.* 4609
).	" "	Oct. 12	11 18 .5	1 05 .3	+0 57	*A.N.* 4609
0.	(133) *Cyrene*	Dec. 6	10 27 .8	5 30 .4	+32 01	*A.N.* 4621
1.	(115) *Thyra*	Dec. 31	8 02 .9	5 49 .1	+36 20	*A.N.* 4625
2.	(139) *Juewa*	Dec. 31	10 18 .9	6 45 .7	+40 46	*A.N.* 4625
3.	(119) *Althæa*	1913 Feb. 25	11 13 .3	10 27 .2	+2 40	*A.N.* 4636

One visual observation made at the Students' Observatory by Mr. S. B. NICHOLSON is also available for comparison:—

			Gr.M.T.	α (app.)	δ (app.)
14.	(115) *Thyra*	1912 Dec. 5	$19^h 52^m.2$	$6^h 21^m.16$	$+38° 58'.8$

By interpolation from the computed ephemerides of the planets, theoretical positions were obtained for the observation dates as follows:—

		Berlin M.T.	α	δ
1.	(115) *Thyra*	1912 Dec. 4.808	6^h $22^m.2$	+39° 02′
2.	" "	Dec. 5.822	6 21 .1	+38 59
3.	(139) *Juewa*	Dec. 31.787	6 45 .3	+40 46
4.	" "	1913 Jan. 2.800	6 42 .9	+40 48
5.	(119) *Althæa*	Feb. 27.834	10 25 .2	+2 56
6.	" "	Mar. 2.854	10 22 .6	+3 15
7.	(105) *Artemis*	1912 Oct. 7.392	1 10 .0	+2 06
8.	" "	Oct. 10.442	1 07 .3	+1 25
9.	" "	Oct. 12.484	1 05 .6	+0 58
10.	(133) *Cyrene*	Dec. 6.449	5 29 .7	+32 2
11.	(115) *Thyra*	Dec. 31.348	5 48 .8	+36 21
12.	(139) *Juewa*	Dec. 31.443	6 45 .8	+40 45
13.	(119) *Althæa*	1913 Feb. 25.481	10 27 .2	+2 40
14.	(115) *Thyra*	1912 Dec. 5.865	6 21 .1	+38 59

A comparison between the observations and the theoretical positions gives the following residuals:—

		Δα (*O*—*C*)	Δδ (*O*—*C*)
1.	(115) *Thyra*	$+0^m.1$	0′
2.	" "	+0 .1	0
3.	(139) *Juewa*	+0 .1	0
4.	" "	+0 .1	—1
5.	(119) *Althæa*	0 .0	0
6.	" "	0 .0	+1
7.	(105) *Artemis*	—0 .3	—1
8.	" "	—0 .1	—1
9.	" "	—0 .3	—1
10.	(133) *Cyrene*	+0 .7	—1
11.	(115) *Thyra*	+0 .3	—1
12.	(139) *Juewa*	—0 .1	+1
13.	(119) *Althæa*	0 .0	0
14.	(115) *Thyra*	+0 .1	0

With the exception of the α residual for (133) *Cyrene,* and the α residuals for two positions of (105) *Artemis* and for one of (115) *Thyra,* all of these being Heidelberg observations, the residuals are zero or within the errors of computation. No reason can be assigned for the three α residuals of $0^m.3$ each, except that the Heidelberg observations are only approximately given; but with reference to the $0^{m}.7$ residual for (133) *Cyrene* it may be said that the tables for that planet could not have been expected to hold as accurately as the others, because its mean motion is roughly commensurable with that of *Jupiter*, in which case HANSEN'S method is more or less indeterminate. Whether the residual is due to this cause or to neglected perturbations or to the inclusion in the final correction of the elements of a position erroneously identified by the observer, will form the subject of further investigation.

Thus several years after the last comparisons were made, the theoretical positions based upon LEUSCHNER'S tables are found to check almost exactly with the observations. The correction to the 1915 *Jahrbuch* ephemeris for (139) *Juewa*, noted in No. 4625 of the *Astronomische Nachrichten*, is not confirmed by the preceding comparisons.

BERKELEY ASTRONOMICAL DEPARTMENT,
UNIVERSITY OF CALIFORNIA,
1913, April.

THE DAVIDSON TRANSIT AND ZENITH TELESCOPE

BY OSCAR W. LANZENDORF.

When the Students' Observatory was organized more than twenty years ago, a Davidson transit and zenith telescope simliar to the kind then in use in Coast Survey work was installed. It is equipped with a 3-inch object glass, latitude circle, striding level, and a micrometer which can be used in right ascension or declination. It is used mainly to determine time, latitude, and longitude.

During its twenty years' service it has been constantly used by students. Due to the more or less rough usage it has thus received, and to general wear, the instrument no longer gave consistent results. These anomalies were investigated by Messrs. P. W. STONER and H. J. KESNER in 1910-11, and as a result the instrument was sent back to the makers in 1911 to be remodeled. Upon its reinstallation at the observatory it was necessary again to determine its constants, which may have been changed as the result of remodeling.